# DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENT

The significance and reasons for the limitations of the alloying components in the aluminum alloy piping material for automotive tubes having excellent corrosion resistance and formability according to the present invention are described below. Mn functions to increase the strength and improve the corrosion resistance, in particular, pitting corrosion resistance, of the aluminum alloy. The preferred range for the Mn content is 0.3 to 1.5%. If the Mn content is less than 0.3%, the improvement effect will become insufficient. If the Mn content exceeds 1.5%, the corrosion resistance is reduced due to the formation of a multitude of Mn-based compound grains. The more preferred range for the Mn content is 0.8% or more and less than 1.2%.

Cu functions to improve the strength of the alloy. The preferred Cu content is in the range of 0.20% or less (excluding 0%). If the Cu content exceeds 0.20%, the corrosion resistance is reduced. The more preferred range for the Cu content is 0.05 to 0.10%.

Ti exists in two types of regions, i.e., one that contains a high concentration of Ti and the other with a lower Ti concentration, which are distributed as alternate layers in the thickness-wise direction. Since the region with a lower Ti concentration corrodes in preference to the region with a higher Ti concentration, the resultant corrosion takes a stratified form where the development of corrosion in the thickness-wise direction is hindered, thereby contributing to an improvement in pitting corrosion resistance, intergranular corrosion resistance, and crevice corrosion resistance. The preferred Ti content is in the range of 0.10 to 0.20%. If the Ti content is less than 0.10%, the improvement

effect is insufficient. If the Ti content exceeds 0.20%, coarse compounds are formed in large quantities, making the piping material prone to crack at the time of expansion work.

Fe reduces the crystal grain size after annealing. The preferred content of Fe is in the range above 0.20% but not more than 0.60%. If the Fe content is 0.20% or less, the effect is insufficient. If the Fe content exceeds 0.60%, a large quantity of Fe-based compound grains are formed, resulting in a reduced corrosion resistance.

Si, as is the case with Fe, reduces the crystal grain size after annealing. The preferred content of Si is 0.50% or less (excluding 0%). If the Si content exceeds 0.50%, grains of Si-based compounds are formed in large quantities to cause the corrosion resistance to deteriorate.

Mg acts to improve the strength and reduce the crystal grain size. The preferred content of Mg is 0.4% or less (excluding 0%). If the Mg content exceeds 0.4%, it gives rise to insufficient extrudability as well as a reduced corrosion resistance. The more preferred range for the Mg content is 0.20% or less.

Cr and Zr, similarly with Ti, exist in two types of regions, i.e., one that contains high concentrations of these elements and the other with lower concentrations, which are distributed as alternate layers in the thickness-wise direction. Since the regions with lower concentrations of Cr and Zr corrode in preference to those with higher concentrations, the resultant corrosion takes a stratified form where the development of corrosion in the thickness-wise direction is hindered, thereby contributing to improvements in pitting corrosion resistance, intergranular corrosion resistance, and

crevice corrosion resistance. The preferred content of Cr and Zr is in the ranges of 0.01 to 0.2% for Cr and 0.01 to 0.2% for Zr. At concentration levels below the specified minimum, the improvement effect becomes insufficient. If these elements are above the specified maximum, coarse compounds are formed during casting, making the piping material prone to cracking at the time of expansion work.

Zn, In, and Sn act to modify this form of corrosion into a uniform corrosion type, thereby inhibiting the development of pitting corrosion in the thickness-wise direction. The preferred content for Zn, In, and Sn is in the ranges of 0.01 to 0.1% for Zn, 0.001 to 0.05% for In, and 0.001 to 0.05% for Sn, respectively. At concentration levels below the specified minimum, the improvement effect becomes insufficient. If these elements are above the specified maximum, the corrosion resistance is reduced.

It is important for the aluminum alloy piping material of the present invention that the average crystal grain size be 100 μm or less, and that Ti-based compounds having a grain size (circle equivalent diameter) of 10 μm or more do not exist as an aggregate of two or more serial compounds in a single crystal grain. If the average grain size exceeds 100 μm, elongation and deformation of the piping material become uneven at the time of expansion work, making the material prone to develop an orange peel surface or cracks. Even if the average grain size is 100 μm or less, if Ti-based compounds having a grain size of 10 μm or more exist as an aggregate of two or more serial compounds in a single alloy crystal grain as shown in FIG. 1, stress concentrates during expansion work, whereby cracks occur from the Ti-based compounds.

The aluminum alloy piping material for automotive tubes according to the present invention is manufactured by casting a molten alloy metal having the above composition into a billet by continuous casting (semi-continuous casting), providing the billet with a homogenization treatment, and forming the homogenized billet into a tubular shape by hot extrusion, cold drawing the hot-extruded product, and annealing the resulting product to obtain an O temper.

In the present invention, it is preferable that in the above manufacturing steps, the reduction ratio of cold drawing be 30% or more, the total reduction ratio of hot extrusion and cold drawing be 99% or more, and the temperature increase rate during annealing be 200°C/h or more. The reduction ratio is expressed by {(cross-sectional area before forming ~ cross-sectional area after forming) / (cross-sectional area before forming)} × 100%.

If the reduction ratio of cold drawing is less than 30%, the crystal grain size after annealing will become coarse, allowing Ti-based compounds to exist as an aggregate of two or more serial compounds in a single crystal grain, thereby making the material prone to develop cracks at the time of expansion work. If the total reduction ratio of hot extrusion and cold drawing is less than 99%, since the Ti-based compounds formed during casting are not adequately dispersed and tend to exist at one location, cracks develop at the time of expansion work.

The smaller the temperature increase rate applied during annealing, the larger the crystal grain size after annealing, allowing Ti-based compounds to exist as an aggregate of two or more serial compounds in a single crystal grain, thereby making the material prone to

cracking at the time of expansion work. In particular, in the case where the aluminum alloy piping material after cold drawing is annealed in a coil-like shape, bringing the temperature increase rate to a sufficiently high level results in a substantial cost increase. The present invention, however, makes it possible to obtain fine crystal grains by setting the temperature increase rate to 200°C/h or more.